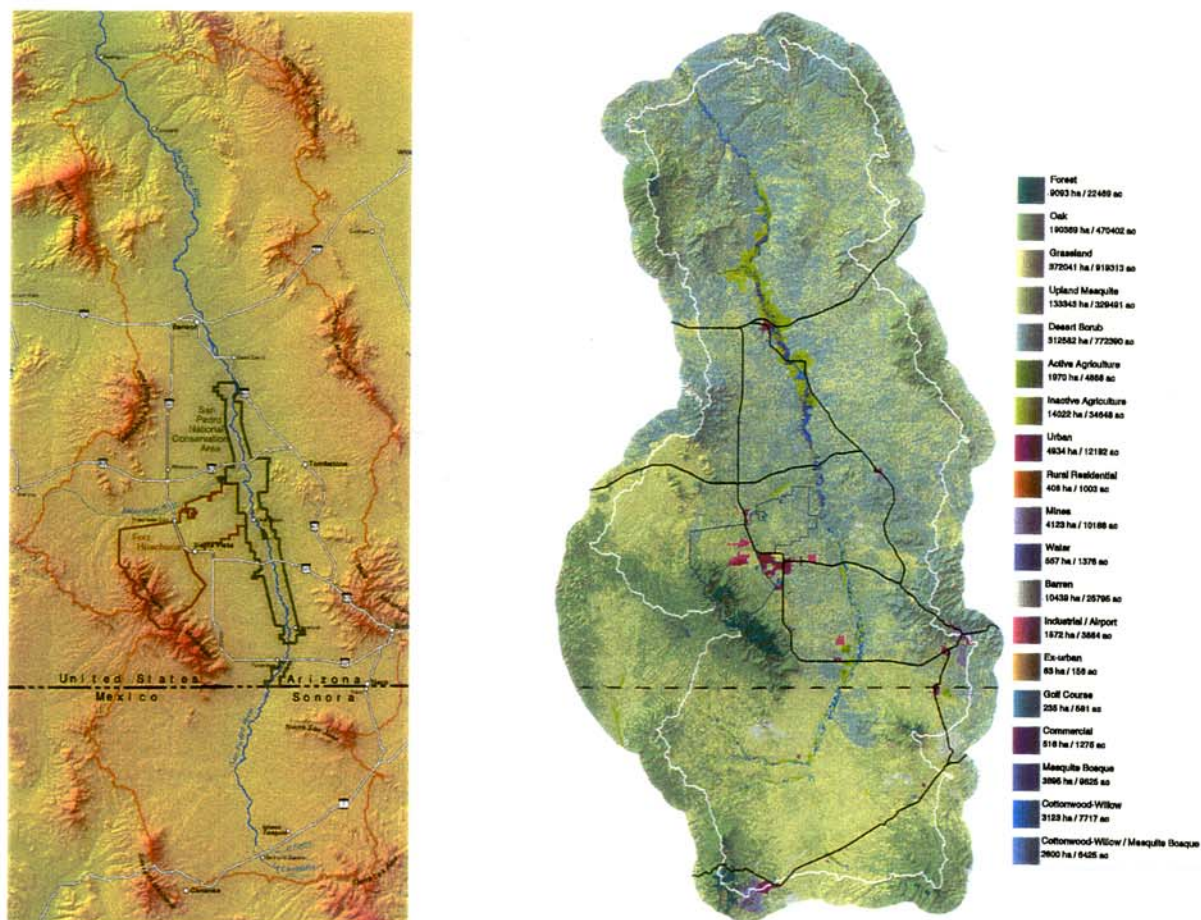


Summary Report

ALTERNATIVE FUTURES FOR THE UPPER SAN PEDRO RIVER BASIN ARIZONA, U.S.A., AND SONORA, MEXICO



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ALTERNATIVE FUTURES FOR THE UPPER SAN PEDRO RIVER BASIN ARIZONA, U.S.A., AND SONORA, MEXICO

This study explores how urban growth and change in the Upper San Pedro River Basin might influence the hydrology and biodiversity of the area over the next 20 years. This report is intended to outline the scope, methods, and principal findings of the research. A longer technical report is forthcoming.

The study was conducted by a team of investigators from Harvard University Graduate School of Design, the Desert Research Institute, the University of Arizona, Instituto del Medio Ambiente y el Desarrollo Sostenible del Estado de Sonora (I.M.A.D.E.S.), the United States Army Training and Doctrine Command, and the United States Army Engineer Research and Development Laboratory, with the cooperation of the regional planning agencies of the area, the Semi-Arid Land-Surface-Atmosphere Program (SALSA) and Fort Huachuca. The research was funded by a grant obtained by the U.S. Army Training and Doctrine Command's Environmental Division from the Department of Defense Legacy Resources Management Program.

Because of its international, regional and local importance, and the intense controversy surrounding planning issues, the San Pedro River Basin has been well studied in recent years. This report seeks to contribute to the public debate in three ways: one, by considering the Sonora and Arizona portions of the river basin as a single area; two, by investigating the widest range of policy issues which have been raised by stakeholders in the past; and three, by adding spatial and temporal dimensions to anticipated changes and their impacts. The sole purpose of this research publication is educational: to provide information to the many stakeholders and jurisdictions of the region regarding issues, strategic planning choices, and their possible consequences related to the built and natural environment.

The study area includes the Upper San Pedro River Basin from its headwaters near Cananea, Sonora, northwards 187.8 km (116.7 miles) to Redington, Arizona. Adjacent areas necessary for the maintenance of regional biodiversity are also included. In total, the analysis covers 996 sq. km. (382 sq. mi.). The Upper San Pedro River Basin is a transition area between the Sonoran and Chihuahuan deserts and is internationally recognized for its biodiversity. It supports the second highest land mammal diversity in the world, and provides habitat for almost 390 bird species, including 50 neotropical migrant species. Topography, climate, and vegetation vary across the watershed. Elevation ranges from 900 to 2,900 meters (3000 to 9500 feet). Annual rainfall ranges from 300 to 750mm (12 to 30 inches). Vegetation types include desert scrub, grassland, oak-woodland savannah, mesquite woodland, riparian forest and coniferous forest. Because the watershed lies partly in Sonora and partly in Arizona, it is subject to widely different laws, regulations, and land use practices.

In 1988, the United States Congress created the San Pedro Riparian National Conservation Area (S.P.R.N.C.A.) in recognition of this ecosystem's unique biological importance. However, the protection afforded by this action does not guarantee the river basin's long term viability as habitat for the species that live there. Changes in development, the water table, or river flow can greatly impact riparian vegetation and the animal species that live in the region. Understanding the processes that relate land use and development to groundwater recharge, stream flow, vegetation, and habitat is of critical importance to the land management of the entire region.

To represent the dynamic processes at work in this study area, a computer based Geographic Information System (G.I.S.) was used to organize spatially explicit and publicly available data on the region. The information in the G.I.S. is based on data on conditions in the study area during the period 1997-2000 (referred to here as 2000), which defines the reference period against which impacts of future change are measured.

A suite of process models is used to describe and evaluate how the current landscape works, and to assess the potential impact of each of the Alternative Futures and their variations relative to the conditions in 2000. Just as issues facing the region are interrelated, the computer models are

interlinked. First, the development model evaluates the attractiveness of the available land for five kinds of development: commercial, and urban, suburban, rural, and exurban housing. It then simulates the urbanization of the region under different Scenarios for change. The hydrological model evaluates change in terms of head configuration, loss of groundwater storage, stream capture volume, and flows in the San Pedro River. The vegetation model responds to changes in the hydrologic regime combined with changes in fire and grazing management practice. The predicted new vegetation patterns form the basis for a three part assessment of regional biodiversity: the landscape ecological pattern, a group of single species potential habitat models, and vertebrate species richness. Finally, a visual model assesses potential impact on the region's landscape in terms of residents' scenic preferences.

Since no single vision of the future can be certain, it is preferable to consider several Alternative Futures that encompass a spectrum of possibilities. Therefore, this study generates several alternative policy Scenarios and examines the resulting range of Alternative Futures that the region might experience. To help generate the Scenarios in Arizona, the Scenario Guide questionnaire was developed. It was based on three groups of issues central to public debate in the region that are currently being considered by area residents and elected officials. The questions addressed the development of the area, water use, and land management. The answers, interpreted into a set of assumptions and choices about policy, became a range of Scenarios. A separate but similar set of questions concerning the Sonoran part of the basin was applied to the Mexican portion.

Three groups of Scenarios are projected to 2020 via the development model. The first, called PLANS, is based on the research team's interpretation of existing planning documents and land use practices of the region. The second, CONSTRAINED, investigates lower than forecast population growth and tightly controlled development zones. The third, OPEN, anticipates greater than forecast population growth and low density development across the region. Each of these is expanded by variations that alter key policy positions. The variations provide a basis for better understanding which actions will produce the greatest effects.

Ten Scenarios guided the model of future development, creating ten Alternative Futures.

PLANS (Table 1) is based on the research team's interpretation of current Arizona and Sonora plans, and a forecast population of 95,000 in 2020 in the Arizona portion of the study area. PLANS 1 increases the Arizona population at a rate double the present forecast, but is otherwise the same as Plans.

PLANS 2 maintains the predicted Arizona population growth, and doubles the population in Cananea, Sonora, with corresponding increases in mining activity, but with no change to Sonora's conservation areas.

PLANS 3 maintains the predicted Arizona and Sonora population growth, but constrains growth in Arizona to urbanized areas.

CONSTRAINED (Table 2) assumes lower than forecast population growth in Arizona. Development is concentrated in existing developed areas. It includes very large lot residential development.

CONSTRAINED 1 varies in that the on-base population of Fort Huachuca is doubled.

CONSTRAINED 2 varies in that Fort Huachuca is closed.

OPEN (Table 3) assumes higher than forecast population growth in Arizona, with major reductions of development control. Sonora remains as forecast.

OPEN 1 is the same as OPEN, except that Fort Huachuca closes, and there are increased controls on rural residential development.

OPEN 2 doubles the on-base population of Fort Huachuca, and doubles the population of Sonora, with corresponding increases in mining activity, but no change to Sonora's conservation areas.

Table 1. PLANS SCENARIO

POPULATION

- Population increase is as forecast (2020 population of 95,000).
- 03% of the new population live in Rural homes.
- 15% of the new population live in Suburban homes.
- 80% of the new population live in Urban homes.
- 02% of the new population live in Exurban homes.
- The minimum size of a rural residential lot is 4 acres in the Upper San Pedro River Basin.
- The minimum size of a rural residential lot is 4 acres if within 1 mile of the SPRNCA.
- The Fort remains open and stays at its current size.
- Kartchner Caverns attracts 200,000 people per year in 2020.
- Growth in Sonora is moderate.

WATER MANAGEMENT

- Domestic per capita consumption from public and water company sources decreases from 1995 levels by 20% (48 gallons per person per day).
- Domestic per capita consumption from individually owned sources decreases from 1995 levels by 40% (75 gallons per person per day).
- An Irrigation Exclusion Area is created within the Upper San Pedro River Basin; all proposed irrigated agriculture within 1 mile of the Upper San Pedro River is prohibited; existing water rights for irrigated agriculture within 1 mile of the San Pedro River are purchased and retired.
- Cottonwood and willow trees in the riparian zone along the San Pedro are not removed.
- Upland mesquite is not removed.

LAND MANAGEMENT

- Ranching in the San Pedro River Basin on federally owned lands is removed.
- The leasing of state-owned land in the San Pedro River Basin for conservation purposes is allowed by competitive bidding.
- Fires are prescribed as a part of a vegetation management plan for the Upper San Pedro River Basin.
- Areas along the San Pedro River to the Mexican border that are not protected as part of the SPRNCA are purchased for conservation purposes.
- Large natural patches (greater than 5,000 acres) and their connecting natural corridors are protected.
- Potential habitat for Endangered species is protected.
- Potential habitat for Threatened species is protected.
- Gila Monster, Southwestern Willow Flycatcher, Northern Goshawk, Beaver, Sonoran Pronghorn, and Jaguar potential habitat is protected.
- No areas are protected based on Species Diversity.
- Basin scale GAPS (from Arizona GAP Analysis) are not protected.
- Views of mountain ridge lines as seen from major state roads are protected.
- Views of the riparian vegetation corridor as seen from major state roads are protected.

Table 2 CONSTRAINED SCENARIO

POPULATION

- Population increase will be 50% less than the current forecast (2020 population of 78,500).
- 90% of the new population will live in Urban homes.
- 10% of the new population will live in Exurban homes.
- The minimum size of a rural residential lot is 4 acres in the Upper San Pedro River Basin.
- The minimum size of a rural residential lot is 40 acres if within 1 mile of the SPRNCA.
- The Fort remains open but is reduced to only those units and activities associated with the Electronic Proving Ground; all other units and activities are transferred to other facilities. (Approximately 1500 active duty troops, civilian contractors, and support personnel remain at Fort Huachuca.)
- Kartchner Caverns attracts 1,000,000 people per year in 2020.
- Growth in Sonora is moderate.

WATER MANAGEMENT

- Domestic per capita consumption from public/company sources decreases from 1995 levels by 20% (48 gallons per person per day).
- Domestic per capita consumption from individually-owned sources decreases from 1995 levels by 20% (100 gallons per person per day).
- All irrigated agriculture in the Upper San Pedro River Basin is removed.
- Approximately half of the Cottonwood and willow trees in the riparian zone along the San Pedro are removed by the clearing of selected areas that are then managed to maintain a grassland ecosystem.
- Approximately half the upland mesquite is removed by clearing selected areas that are managed to maintain a grassland ecosystem.

LAND MANAGEMENT

- Ranching in the San Pedro River Basin on state-owned lands is removed.
- The leasing of state-owned land in the San Pedro River Basin for conservation purposes is allowed by competitive bidding.
- Fires are prescribed as a part of a vegetation management plan for the Upper San Pedro River Basin.
- Areas along the San Pedro River that are not protected as part of the San Pedro Riparian National Conservation Area between Cascabel and the Mexican border are purchased for inclusion in the SPRNCA.
- Mexico will establish and manage an extension of the SPRNCA in Sonora; conserved habitat will extend to the town of José Maria Morelos, Mexico.
- Large natural patches (greater than 5,000 acres) and their connecting natural corridors are protected.
- Potential habitat for Endangered species is protected.
- Potential habitat for Threatened species is protected.
- Gila Monster, Southwestern Willow Flycatcher, Northern Goshawk, Beaver, Sonoran Pronghorn, and Jaguar potential habitat is protected.
- Contiguous habitat areas that contain at least 195 vertebrate species is protected.
- Basin scale GAPS are protected.
- Views of mountain ridge lines as seen from major state roads are protected.
- Views of the riparian vegetation corridor as seen from major state roads are protected.

Table 3 OPEN SCENARIO

POPULATION

- Population increase is 50 % greater than the current forecast (2020 population of 111,500).
- 60% of the new population live in Rural homes.
- 15% of the new population live in Suburban homes.
- 15% of the new population live in Urban homes.
- 10% of the new population live in Exurban homes.
- The minimum size of a rural residential lot is 1 acre in the Upper San Pedro River Basin.
- The minimum size of a rural residential lot is 1 acre if within 1 mile of the SPRNCA.
- The Fort closes and all its facilities and land are used for economic growth in the civilian sector.
- Kartchner Caverns attracts 200,000 people per year in 2020.
- Growth in Sonora is moderate.

WATER MANAGEMENT

- Domestic per capita consumption from public or water company sources remains at 1995 levels (60 gallons per person per day).
- Domestic per capita consumption from individually owned sources remains at 1995 levels (125 gallons per person per day).
- An Irrigation Non-Expansion Area (I.N.A.) is created within the Upper San Pedro River Basin; all existing irrigated agriculture remains, but proposed irrigated agriculture within 1 mile of the Upper San Pedro River is prohibited.
- Cottonwood and willow trees in the riparian zone along the San Pedro are not removed.
- Upland mesquite is not removed.

LAND MANAGEMENT

- Ranching in the San Pedro River Basin continues at its current intensity and locations.
- The leasing of state-owned land in the San Pedro River Basin for conservation purposes is not allowed.
- Fires are not prescribed, and to the greatest extent possible, all fires are suppressed.
- Areas along the San Pedro River to the Mexican border south of the current SPRNCA are purchased for conservation purposes.
- Large natural patches and their connecting natural corridors are not protected.
- Potential habitat for Endangered species is protected.
- Potential habitat for Threatened species is not protected.
- There is no conservation or management of individual species.
- No areas are protected based on Species Diversity.
- Basin scale GAPS (from Arizona GAP Analysis) are not protected.
- Views of mountain ridge lines as seen from major state roads are not protected.
- Views of the riparian vegetation corridor as seen from major state roads are not protected.

Applying the process models to the Alternative Futures for 2020 and comparing the results with the reference period 2000 yields impact assessments. Urbanization and agriculture are the major environmental stresses affecting the San Pedro River Basin. Direct impacts on hydrology and habitat are caused by activities such as grading, paving, plowing, grazing, irrigation and water use. Indirect effects include modified hydrology, fire suppression and vegetation change. Indirect effects may remain unnoticed by the casual observer, but their cumulative effects can be as detrimental to biodiversity as the direct impacts. Both direct and indirect impacts are assessed, with each impact assessment revealing one aspect of how an Alternative Future is predicted to change the landscape.

In general, the three OPEN Alternative Futures have the greatest attractiveness to developers. They provide the largest area of developable land from which to choose, resulting in lower land prices and lower housing costs. The three OPEN Alternative Futures have the greatest negative impact on groundwater storage and recharge, substantially accelerating drying of the San Pedro River, increasing vegetation loss, and reducing all of the measures of potential wildlife habitat and visual quality. The OPEN Alternative Futures result in a diffuse pattern of development, and the lowest level of environmental sustainability.

The three CONSTRAINED Alternative Futures, which direct most future development into existing developed areas, cause substantial reduction in attractiveness for developers. These Alternative Futures could alter current development practice, but are dependent upon changes in the nature of the housing market. They have the lowest negative hydrological impacts, reducing the rate of loss of groundwater. They show some improvements in river flow, and increases in riparian vegetation. The CONSTRAINED Alternative Futures also result in least loss and greatest gains in habitat, and in the least harmful impacts on visual quality.

The four PLANS Alternative Futures lie between those of the OPEN and CONSTRAINED Futures, but are closer to the CONSTRAINED Futures in impacts. The PLANS Alternative Futures are attractive to developers, except when urban development is limited to land within current sewer service areas. They result in reduced loss of groundwater, but the water table continues to lower. PLANS Alternative Futures cause environmental and visual impacts that generally represent a slow decline in several important qualities of the region.

The impacts caused by variations in specific assumptions and policies within the Scenarios are tested by comparison of selected Alternative Futures. In all cases, the impact assessments are made from a regional perspective, and are shown in the Summary Table of Impacts. There are locally varied impacts, and these are shown in the accompanying maps. (The technical report will include all maps for all impacts for all Alternative Futures.)

Test 1--PLANS vs. PLANS 1 compares the current plans and forecast population with doubled population growth in Arizona. (This test gives the same result as extending the population growth of the plans scenario another 20 years into the future to 2040, assuming unchanged plans.) The most significant regional difference in impact is on groundwater. Despite the policy assumption of reduced municipal and industrial water demand per capita, the increased population in PLANS 1 overwhelms the assumed water savings, and the groundwater level continues its accelerated decline. There are no other regionally significant environmental differences.

Test 2--PLANS vs. PLANS 2 compares the current plans and population assumptions for Arizona and Sonora with increased growth in Sonora, doubling the town of Cananea and its associated mining. Because of increased groundwater pumping and water use, there is an accelerated rate of lowering of the water table. Many of the secondary environmental impacts are felt in Arizona as well as in Sonora. However, these effects are small relative to the effects in Arizona of Arizona water-use policy choices.

Test 3--PLANS vs. PLANS 3 compares the current plans and population assumptions for Arizona and Sonora with policies that guide Arizona's future development into four zones, Sierra Vista, Benson, Tombstone, and Bisbee. Growth is directed mainly by the provision of

infrastructure in advance of development, but development outside the four zones is not prohibited. The problem of compensation for the development rights of landowners is not addressed. The policy to create development zones has hydrologic and other environmental advantages. It improves attractiveness for urban and suburban development because of available infrastructure, but it reduces the attractiveness of rural and exurban development by reducing the amount of available land. Regionally significant impacts include a doubling of the increase in willow flycatcher habitat when compared to the PLANS Alternative Future.

Test 4—CONSTRAINED vs. CONSTRAINED 1 assesses the effect of doubling the on-base population of Fort Huachuca when policies favoring constrained development are in force. Impacts on development attractiveness and on environmental assessments are insignificant, except for impacts on groundwater. The level of the water table will be affected locally. The proposed gray water treatment plant and recharge are not included in the CONSTRAINED Alternative Futures.

Test 5—CONSTRAINED vs. CONSTRAINED 2 assesses the effect of closing Fort Huachuca and dividing its land between conservation and development. Because it has the lowest forecast population, CONSTRAINED 2 is expected to have the lowest impact on hydrology and habitats. It increases attractiveness for development because of desirable new sites within the Fort property. **Although it has the lowest hydrological impacts as expected, CONSTRAINED 2 continues to cause lowering of the water table.**

Test 6—OPEN vs. OPEN 1 assesses the effect of closing Fort Huachuca when development controls are reduced, and population growth in Arizona is higher than forecast. The minimum exurban lot size is 16 ha. (40 acres). OPEN 1 increases attractiveness for development because of the increase in available land, but for suburban and exurban types, attractiveness decreases because larger lot sizes use up the best available land faster.

Test 7—OPEN vs. OPEN 2 assesses the effect of greatest population growth when development controls are reduced. The population in Arizona and in Fort Huachuca double, and Sonora experiences high growth with the doubling of Cananea. As anticipated, OPEN 2 produces by far the highest impacts on hydrology, with the most rapid depletion of groundwater due mainly to increases in municipal and industrial water use. However, when compared to OPEN, its other regional impacts are not dramatically greater.

A full understanding of the maps and tables produced by the simulation of the ten Scenarios into Alternative Futures for 2020, and of the **seven tests of policy sensitivity** is necessary before detailed strategies can be chosen. There are however, some informative generalizations that can be made from looking at the impact assessments of the ten Alternative Futures and the seven tests of sensitivity to varied policies. If we consider the following to be positive impacts: slowing the decline of groundwater storage; slowing the drying up of the river; retaining or improving wildlife habitats; maintaining or improving species richness; improving attractiveness for developers; and maintaining the beauty of the landscape, we can begin to evaluate the Alternative Futures.

The first, and most important findings involve the fundamental factor for life in an urbanizing desert--**water**. **All of the Scenarios-generated Alternative Futures, even those which are most restrictive of population growth and water use, result in overall loss of groundwater storage, and in decreased stream flow** in the San Pedro River. All alternatives will result in a lowering of the water table near Sierra Vista and Cananea, with a drop in level around Sierra Vista of 10 to 15 meters (33 to 49 feet). However, the alternatives that most restrict irrigated agriculture can result in water table gains to the north of St. David. The San Pedro River will continue to lose flow, under the OPEN and PLANS Alternatives, and in the OPEN Alternatives, the riparian habitat will continue to decline. Those alternatives that restrict irrigated agriculture and especially those that also concentrate development, however, can increase stream flow and improve riparian habitat in parts of the river basin. This can improve species diversity in the region, and benefit those species that depend on this habitat such as the willow flycatcher.

There will be an increasingly fragmented pattern of habitat patches that will cause decline in the quality of the region's landscape ecology. This effect is particularly noticeable in alternatives that create development on and around the lower slopes of the mountains in the region. **Habitat for the pronghorn will decline in all the alternatives, as groundwater losses and changes in grazing and fire management cause the region's extensive grasslands to decline.**

The area will experience a substantial decline in its perceived beauty. This will be especially the case along the major roads as they attract future development, most importantly, State Highway 90, the major approach to Sierra Vista from the north, passing Kartchner Caverns.

While the Scenarios produce a generally negative set of impacts, there is considerable variation, especially between the extremes produced by the CONSTRAINED and OPEN Scenarios. The OPEN Futures result in an accelerated decline in all environmental impact measures. Although they include more developable land, they are not more attractive to developers. The CONSTRAINED Futures will see slower but continued lowering of the water table, and also indicate a slowing of the processes of decline in the San Pedro River, and improved wildlife habitats. The PLANS Scenarios produce Futures that lie between the other two, but are closer to the CONSTRAINED Futures in impacts. The PLANS Scenarios most closely resemble the current Cochise County Plan, and the most likely 2020 projections for Sonora.

Comparison of the Alternative Futures reveals that **policy decisions affecting irrigated agriculture in Arizona cause the greatest impacts on the region's hydrology and ecology.** The CONSTRAINED Scenarios propose removal of all irrigated agriculture in the study area. PLANS Scenarios remove it only within one mile of the Upper San Pedro River, and OPEN Scenarios leave irrigated agriculture policy unchanged, except for prohibiting any agricultural expansion within one mile of the river.

The second most significant policy is development control. Population growth in Arizona, with its accompanying municipal and industrial water demands, is the second largest future consumer of water. It is informative to compare the two Alternative Futures which are most different in their impacts, CONSTRAINED 2 and OPEN 2. OPEN 2 is expected to have the highest harmful impact on the hydrology and environment of the region, which is the case. It has the most rapid depletion of groundwater of any of the Alternative Futures. However, these impacts are not very much more damaging than those generated by other OPEN Scenarios, leading to the conclusion that **the encouragement of population growth and the relaxation of development constraints are very powerful influences on potential negative environmental impacts.**

Third in significance is **growth policy** in Sonora. The high growth assumed for Sonora in PLANS 2 and in OPEN 2 results in greater impacts than in their lower growth counterparts. However, their variance is small when compared to the effects of agricultural and development policies in Arizona.

The effect of Fort Huachuca on the region was tested by selecting one of three policy choices in each Scenario. It would either continue as at present, double in size of on-base population, or be closed. **While local consequences in Sierra Vista may be large, when taken in the context of the entire Upper San Pedro River Basin, the variance associated with the Fort is small when compared with variations caused by agriculture and urbanization in Arizona.**

These findings are not unexpected. The future of the Upper San Pedro River Basin is one that will bring environmental crisis closer to the direct perception of more people.

We do not propose solutions. Many people have views on the problems facing the region, and on the policies that will influence change. Complex assessment of costs and benefits related to policy decisions is beyond the scope of this study. Responsibility for making the critical choices about the future of the region lies in Mexico and Sonora, and in the United States and Arizona, and with the present and future residents of the Upper San Pedro River Basin.

Critical choices will be made over the next twenty years that will determine whether or not the most attractive areas—both for conservation and development—will continue to be attractive. The land allocations made here represent our best projections about where development is likely to occur under various Alternative Futures, and what some of the most important environmental impacts might be. Patterns may change depending on people's preferences for housing and on policy choices. If the people who live in the San Pedro Basin care deeply about preserving areas that will almost certainly be developed in the absence of protection, they must act now.

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Architecture from Harvard University. His research includes spatial analysis and its applications to land and natural resources management. Lozar contributed to the initial acquisition of digital data for the study region.

THOMAS MADDOCK, III is Professor of Hydrology and Water Resources at the University of Arizona and Co-director of the Research Laboratory for Riparian Studies. He has served on the Hydrology Committee of the Lower Rio Grande Adjudication and on the former San Pedro Negotiation Technical Committee. He has won the Joseph Wood Krutch Award for Environmental Service from The Nature Conservancy and the Udall Fellowship from the Udall Center for Studies in Public Policy. He received his B.S. in Mathematics from the University of Houston, his M.S. in Applied Mathematics and his Ph.D. in Environmental Engineering from Harvard University. Maddock, as Principal Investigator at the University of Arizona, was responsible for the extension and development of the hydrology model.

DAVID MOUAT is an Associate Research Professor at the Desert Research Institute, Reno, Nevada. His interests include relating ecological characteristics, including vegetation composition and distribution, to issues of ecosystem health, land degradation, and environmental toxicity. He has developed an integrated environmental assessment model for desertification evaluation. He managed the Department of Defense Strategic Environmental Research and Development Program (SERDP) Project "Assessment and Management of Risks to Biodiversity and Habitat". His Ph.D. is from Oregon State University. He holds a B.A. in Physical Geography from the University of California (Berkeley). Mouat, as Principal Investigator at the Desert Research Institute, was responsible for modeling vegetation change, and for U. S. Government inter-agency coordination.

WINIFRED ROSE is an ecologist working for the Land Management Laboratory, U.S. Army Engineer Research and Development Center, in Champaign, IL. Her B.S. in Soil Science and Land Management is from Cornell University, her M.S. in Ecology and Environmental Management is from Arizona State University, and her M.A. in Political Science is from the University of Illinois. Rose, as Principal Investigator for E.R.D.C., contributed to the formulation of the study.

RICHARD PEISER is the Michael D. Spear Professor of Real Estate Development at the Harvard Graduate School of Design, where he teaches real estate finance and development. He was founder and director of the University of Southern California's Master of Real Estate Development Program. He is a trustee and senior fellow of the Urban Land Institute. Peiser received his B.A. from Yale University, his M.B.A. from Harvard, and his Ph.D. in Land Economy from Cambridge University (U.K.). He is the author of Professional Real Estate Development: The ULI Guide to the Business and was Executive Editor of The Lusk Review for Real Estate Development and Urban Transformation. Peiser was responsible for the design of the development model, and for the surveys that defined attractiveness for development within the region.

ALLAN SHEARER is a Research Fellow at Harvard University. He received his A.B. from Princeton University and his Master in Landscape Architecture from Harvard University. He teaches landscape history at the Boston Architectural Center, has practiced landscape architecture, and was project coordinator for the Camp Pendleton research project. Shearer was Executive Officer for this study, and contributed in many ways to all of its aspects. He was responsible for the Scenario Guide.

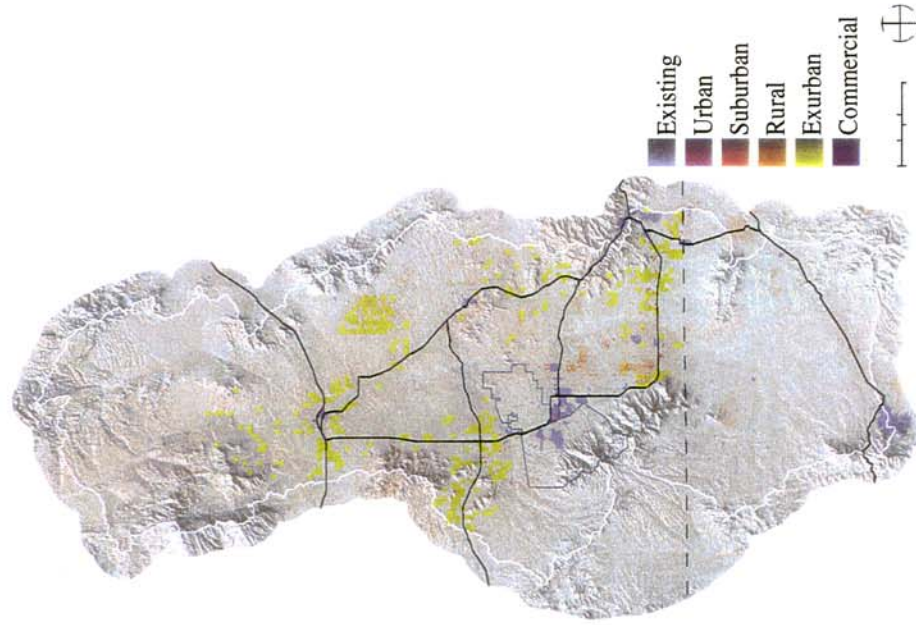
EDITING: Carl Steinitz, Tess Canfield, Allan Shearer

GRAPHICS: Scott Bassett, Michael Flaxman, Tereza Flaxman, Michael Doyle, Tomas Goode

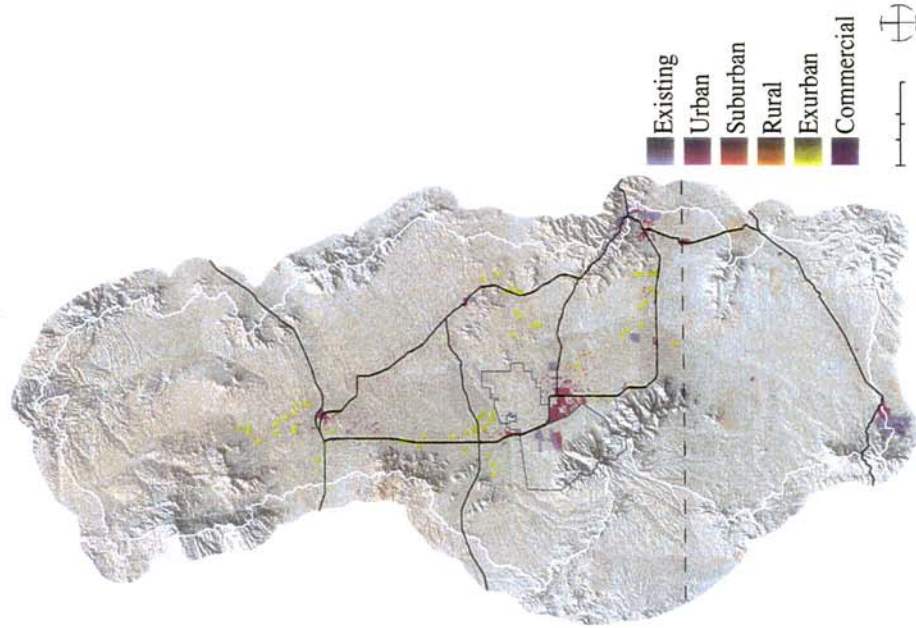
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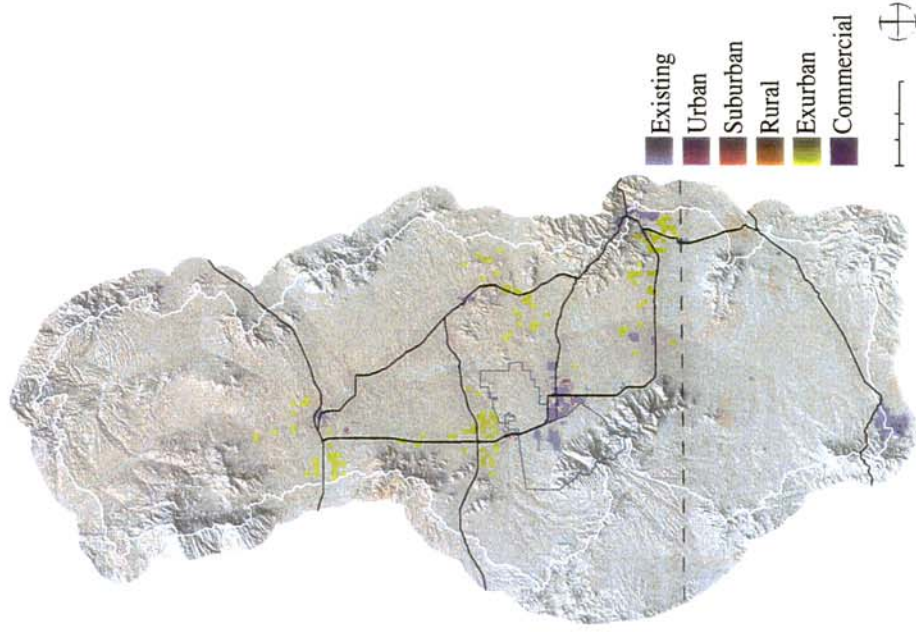
	LANDSCAPE ECOLOGY	SINGLE SPECIES POTENTIAL HABITAT										SPECIES RICHNESS	VISUAL	
		change in willow flycatcher primary secondary habitat ha	change in gila monster habitat ha	change in beaver habitat ha	change in pronghorn habitat ha	change in jaguar habitat ha	threatened and endangered species change in potential habitat ha	change in average number of vertebrate species spp. per cell	number of gap species in reserves	change in average visual value of views by cell	decline in positive visual value ha			
		687,983	9577	146,185	208,993	6469	253,802	320,926	136,329	167.69 avg	4	3.63	570,862	
Baseline 2000														
PLANS	-6466	3113	0	791	-241	-22546	4534	1175	0.56	2	-0.06	49,076		
PLANS 1	-9632	2863	0	547	-374	-22866	4225	1045	0.37	2	-0.07	54,671		
PLANS 2	-9302	2852	0	801	-530	-22827	3946	993	0.51	4	-0.07	49,790		
PLANS 3	-1601	6352	0	967	-251	-22456	4629	1210	0.61	1	-0.05	43,851		
CONstrained	-4232	6852	84	1664	1235	-21757	5344	1464	0.93	1	-0.05	49,220		
CONstrained 1	-15503	6812	80	1209	1352	-21950	5282	1453	0.9	1	-0.05	50,652		
CONstrained 2	-15503	6819	80	1209	1235	-21950	5291	1460	0.9	1	-0.06	50,870		
OPEN	-67486	-2130	-67	-2437	-3399	-32306	-8360	-3185	-1.04	2	-0.13	79,983		
OPEN 1	-101445	-1985	-511	-2637	-3353	-30613	-9444	-3334	-1.15	2	-0.13	84,106		
OPEN 2	-49991	-2146	-14	-2545	-3451	-30717	-8481	-3281	-0.94	4	-0.10	66,485		



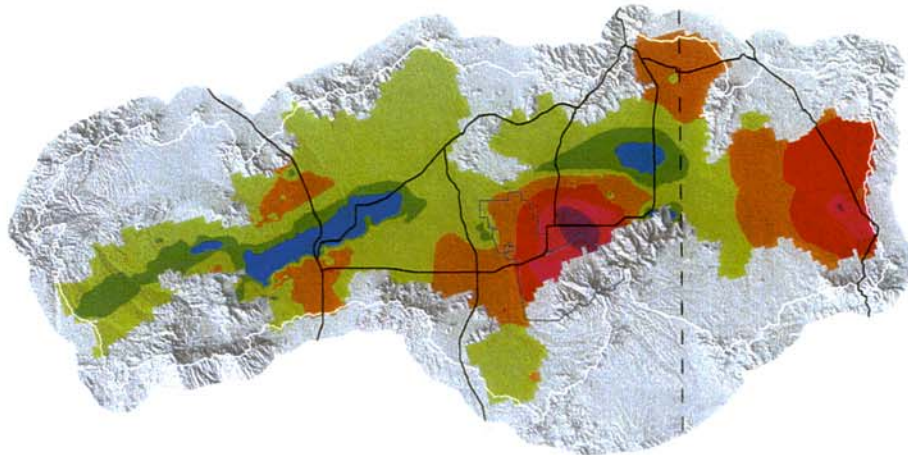
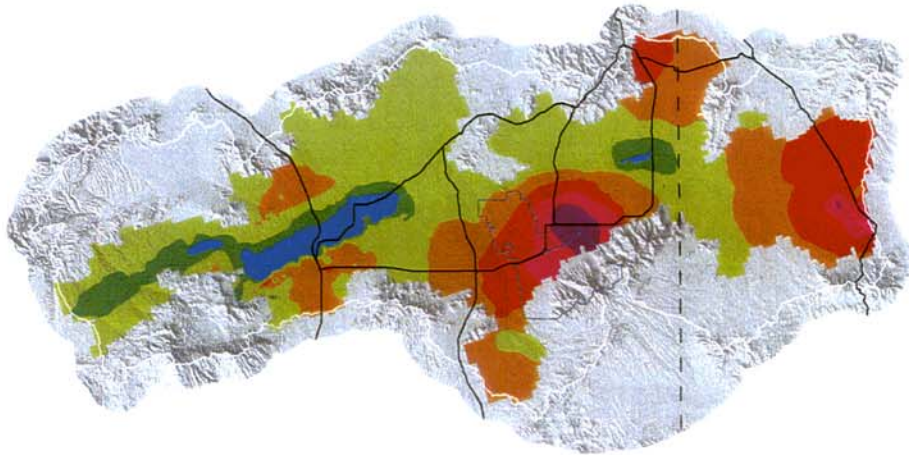
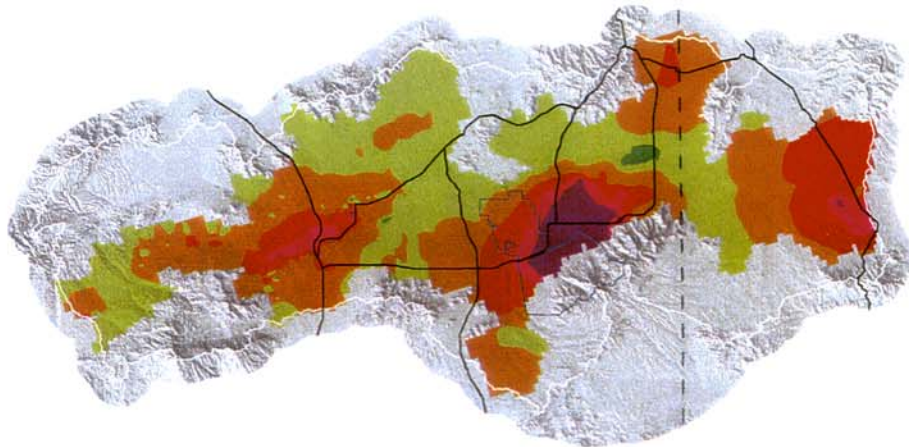
Development
Open 2000-2020

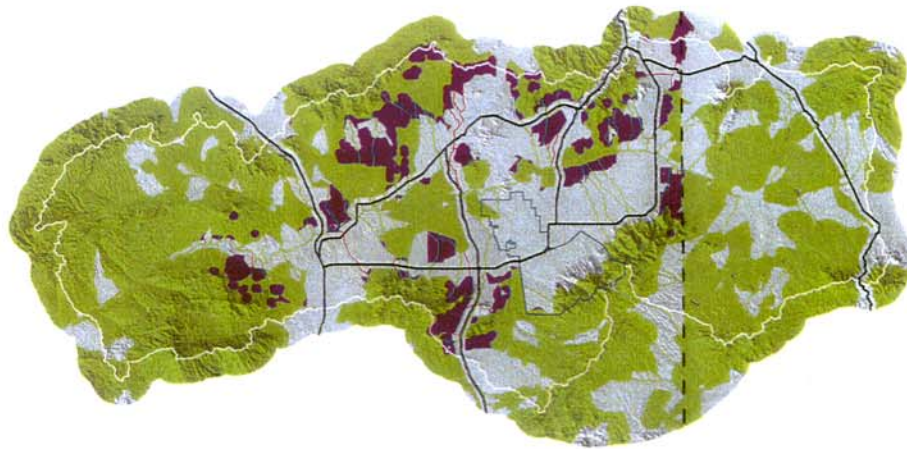


Development
Plans 2000-2020

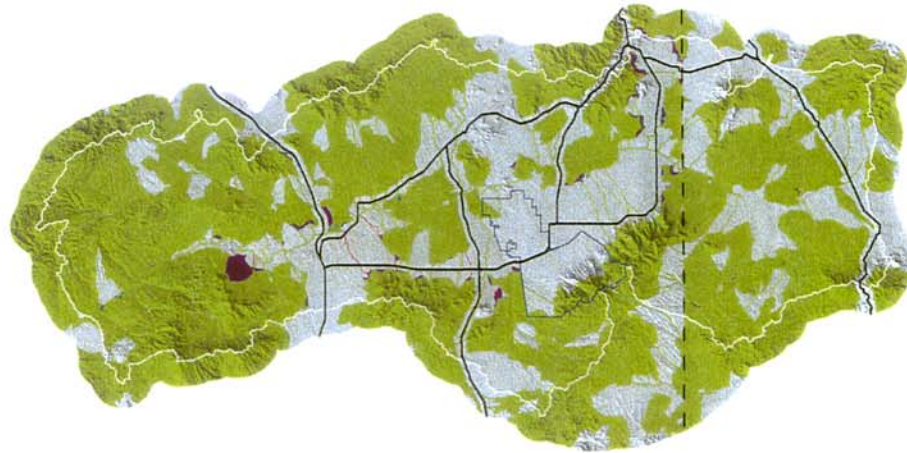


Development
Constrained 2000-2020

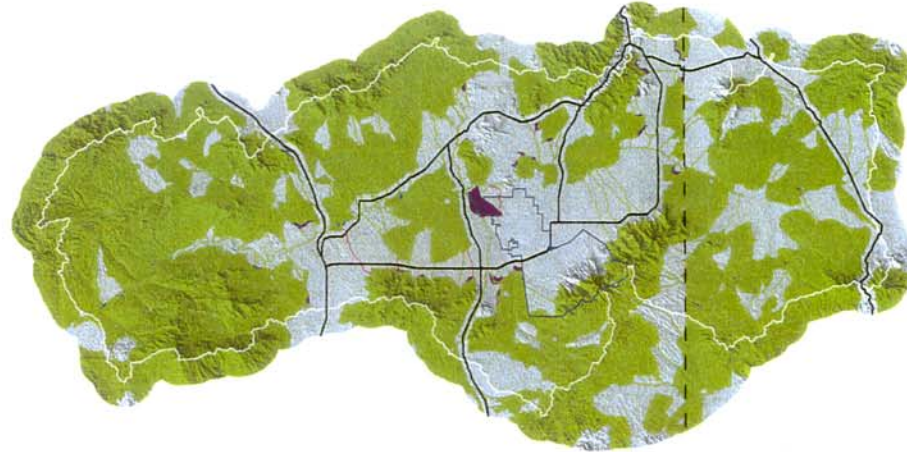




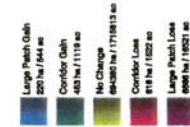
Landscape Ecol. Pattern
Open: Impact, 2000-2020

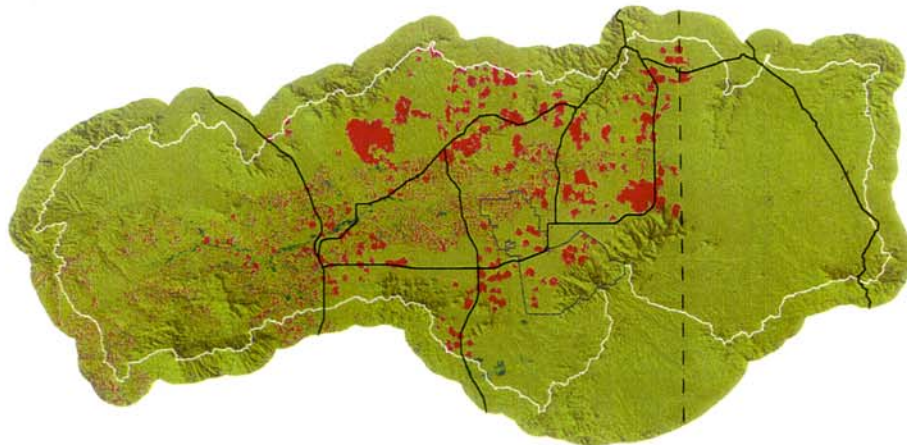


Landscape Ecol. Pattern
Plans: Impact, 2000-2020



Landscape Ecol. Pattern
Cons: Impact, 2000-2020





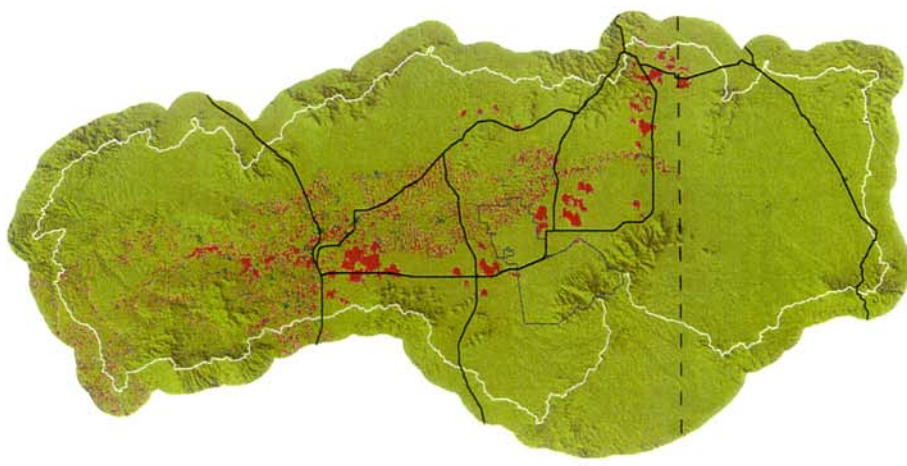
Visual
Open: Impact, 2000-2020



Visual Value Gain
7900 ha / 18709 ac

No Change
87829 ha / 2417262 ac

Visual Value Loss
7900 ha / 18709 ac



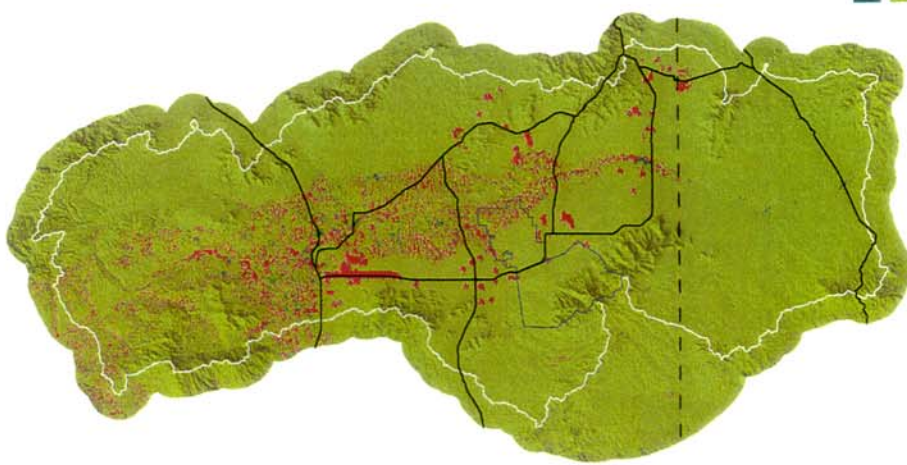
Visual
Plans: Impact, 2000-2020



Visual Value Gain
8500 ha / 18803 ac

No Change
101382 ha / 2268607 ac

Visual Value Loss
48078 ha / 107287 ac



Visual
Cons: Impact, 2000-2020



Visual Value Gain
4827 ha / 10789 ac

No Change
1011728 ha / 2268578 ac

Visual Value Loss
4820 ha / 107623 ac





Stream
Cons: Impact, 2000-2020



Stream
Plans: Impact, 2000-2020



Stream
Open: Impact, 2000-2020